

Sleep duration and blood pressure: a longitudinal analysis from early to late adolescence

INÊS PACIÊNCIA^{1,2}, JOANA ARAÚJO^{1,3,4} and ELISABETE RAMOS^{1,3,4}

¹Institute of Public Health, University of Porto, Porto, Portugal; ²GEAC, INEGI – Institute of Mechanical Engineering and Industrial Management, Porto, Portugal; ³EPIUnit – Institute of Public Health, University of Porto, Porto, Portugal; ⁴Department of Clinical Epidemiology, Predictive Medicine and Public Health, University of Porto Medical School, Porto, Portugal

Keywords

adolescents, diastolic and systolic blood pressure, hypertension, sleep

Correspondence

Elisabete Ramos, Clinical Epidemiology, Predictive Medicine and Public Health, University of Porto Medical School, Alameda Professor Hernâni Monteiro, 4200-319 Porto, Portugal.

Tel.: +351 225 513 652;

fax: +351 225 513 653;

e-mail: eliramos@med.up.pt

Accepted in revised form 5 May 2016; received 8 January 2016

DOI: 10.1111/jsr.12433

SUMMARY

The aim of this study was to evaluate the association between sleep duration and blood pressure using a cross-sectional and longitudinal approach. As part of a population-based cohort, 1403 adolescents were evaluated at 13 and 17 years old. Sleep duration was estimated by the difference between self-reported usual bedtime and wake-up time. Blood pressure was measured using the auscultatory method. Regression coefficients (β) and respective 95% confidence intervals were computed to evaluate the association between sleep duration and blood pressure, using linear regression models adjusted for practice of sports and body mass index at 17 years old. The mean (standard deviation) sleep duration at 13 years old was 9.0 (0.76) h per day, and on average it decreased by 46 min up to 17 years old. The median (25th–75th) systolic blood pressure at 17 years old was 110.0 (103.5–119.0) mmHg in females and 114.0 (106.0–122.0) mmHg in males ($P < 0.001$); for diastolic blood pressure the values were 66.0 (60.0–71.0) and 69.0 (62.0–75.0) mmHg, respectively ($P < 0.001$). In cross-sectional analysis, at 17 years old, after adjustment, a positive association was found between sleep duration and blood pressure, significant only for systolic blood pressure among females [$\beta = 0.730$ (0.005; 1.455)]. In girls, no significant association was found between sleep duration at 13 years old and blood pressure at 17 years old, but in males an inverse association was found between sleep duration at 13 years old and blood pressure at 17 years old significant only for systolic blood pressure [$\beta = -1.938$ (–3.229; –0.647)]. This study found no association between sleep duration at 13 years old and blood pressure at 17 years old in girls, but among males an inverse association was found.

INTRODUCTION

Hypertension is an increasingly prevalent health problem in adults (Chobanian *et al.*, 2003) and adolescents alike, partially reflecting the increasing prevalence of being overweight (Din-Dzietham *et al.*, 2007). Among children and adolescents, the USA National Health and Nutrition Examination Survey (NHANES) showed an increase of 1.4 mmHg in the mean systolic blood pressure (SBP) and 3.3 mmHg for diastolic blood pressure (DBP) from 1988–1994 to 1990–2000 (Muntner *et al.*, 2004). As blood pressure (BP) in adolescence sharply influences adult levels (Lurbe, 2003; Sun *et al.*, 2007), it is important to identify modifiable factors that may be the target of preventive measures at young ages,

and to study if adolescence is a window of opportunity for a potential intervention to prevent hypertension and its consequences later in life.

Sleep patterns among adolescents have been changing over recent decades, accompanying the social constraints, the increase of interactions with peers, school requirements and extracurricular activities (Laberge *et al.*, 2001). Additionally, sleep patterns also change during adolescence: sleep duration decreases from an average of 9.0 (0.7) h per day at 13 years old to 8.1 (0.7) h at 16 years old (Iglowstein *et al.*, 2003).

Sleep deprivation has been described as a possible cause of a set of different health consequences, such as decrease in cognitive performance, mood disturbances, depressive

symptoms and metabolic changes (e.g. reduced leptin levels; Durmer and Dinges, 2005; Knutson *et al.*, 2007). More recently, insufficient sleep has been implicated as a risk factor for development of hypertension amongst children and adults (Nixon *et al.*, 2008; Wang *et al.*, 2015).

Various mechanisms have been suggested as the causal link between sleep duration and hypertension. The effect of sleep duration on the activation of the hypothalamic–pituitary–adrenal axis and on the renin–angiotensin system may be plausible explanations (Kato *et al.*, 2000; Meerlo *et al.*, 2008). However, in adolescence the association between sleep duration and BP remains unclear. Kuciene and Dulskiene (2014) found that short sleep duration was associated with higher BP, while other studies reported a positive (Rey-Lopez *et al.*, 2014) or no association (Shaikh *et al.*, 2010) between sleep duration and BP among adolescents.

From the standpoint of public health, modifiable risk factors, such as behaviours and lifestyles, are the most promising to prevent hypertension and their consequences. Thus, understanding the role of sleep duration in the development of high BP during adolescence could be important to devise more effective interventions.

The aim of this study was to evaluate the association between sleep duration and BP at 17 years old, using a cross-sectional and longitudinal approach.

MATERIALS AND METHODS

This study was developed as part of the Epidemiological Health Investigation of Teenagers in Porto (EPITeen). Eligible participants were adolescents born in 1990, and were enrolled at public and private schools in Porto. The first evaluation was conducted during the 2003/2004 school year, as previously described (Ramos and Barros, 2007). The follow-up took place in the 2007/2008 school year, and adolescents were evaluated following procedures similar to those used at baseline evaluation. The ethics committee of Hospital S. João approved the study, and informed consent was obtained from both adolescents and their legal guardians.

At baseline, 2159 adolescents agreed to participate and provided information at least for part of the planned assessment, resulting in a participation of 77.5%. In the second evaluation, 1716 (79.4%) were reevaluated.

The evaluation included self-administered questionnaires comprising information on social, demographic and behavioural characteristics, and the individual and family history of disease. A physical examination was performed at school, by a team of experienced nurses, nutritionists and physicians.

Information about sleep duration was estimated by the difference between usual bedtimes ('What time do you usually go to bed?') and wake-up times ('What time do you usually wake up?'), regarding the weekdays and during-school period.

Blood pressure was measured by trained doctors or nurses, using the right arm, based on the auscultatory

method with a standard mercury sphygmomanometer, according to the recommendations of the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents (Din-Dzietham *et al.*, 2007). Two measurements were performed after a 10-min rest, and if the difference between the two measurements was greater than 5 mmHg a third measurement was obtained. The average of the two closest measurements was recorded. Hypertension was defined according to the quantitative criteria of the American Academy of Pediatrics (2004): pre-hypertension if SBP and/or DBP were equal to or above the 90th percentile for sex, age and height, but both below the 95th percentile; and hypertension if SBP or DBP was equal to or above the 95th percentile. The categories pre-hypertension and hypertension were grouped into one category – high BP (SBP and/or DBP equal to or above the 90th percentile).

Information about a medical diagnosis of hypertension was gathered separately from the mother and father. A family history of hypertension was considered present when at least one parent reported a medical diagnosis of the condition.

The parental education level was measured as the number of successfully completed years of formal schooling. Participants were classified according to the parent with the higher education level.

Depressive symptoms were assessed using the Beck Depression Inventory II (BDI-II; Beck *et al.*, 1996), a 21-item self-report scale that provides information on current (past 2 weeks) depressive symptoms. The total score ranges from 0 to 63, higher scores reflecting more severe depression. The BDI-II was previously validated in Portuguese adolescents, and 13 was the cut-off defined to classify adolescents presenting depressive symptomatology (Coelho *et al.*, 2002).

Frequency of exercise was assessed using the question: 'How many times/week do you take part in sport or physical activity for at least 20 min outside school?', for which there are six possible close-answers, ranging from never to every day. Based on the frequencies reported, participants that reported any practice were aggregated in the category 'yes', and those who reported 'never' were classified as 'no practice'. Adolescents were classified regarding their use of alcohol and tobacco as never users if they had never drank alcoholic drinks and if they have never smoked; and as drinkers or smokers if they reported to use them or if they reported only to have experimented with those substances.

Caffeine intake was assessed using a food frequency questionnaire (FFQ) concerning the previous 12 months, completed by the adolescent at home with the help of their parents or legal guardians. The FFQ was designed according to Willett and colleagues, and adapted for the Portuguese population (Lopes *et al.*, 2007). The FFQ was then adapted for adolescents, including foods more frequently eaten by this age group (Araujo *et al.*, 2011). The adolescents' version comprised 91 food items or beverage categories, a frequency section with nine possible responses ranging from never to six or more times per day, and an open-ended section for

foods not listed in the questionnaire, but eaten at least once per week. The software Food Processor Plus (version 5.0, 1992; ESHA Research, Salem, OR, USA) based on values from the US Department of Agriculture was used to estimate caffeine intake from the evaluated food intake. Caffeine intake was categorized according to the quartiles of intake into: ≤ 11.74 ; >11.74 and ≤ 23.61 ; >23.61 and ≤ 45.95 ; and >45.95 mg day⁻¹.

Weight and height were measured with the adolescent in light indoor clothes and no shoes. Weight was recorded in kilograms, to the nearest 10th, using a digital scale; and height in centimetres, to the nearest 10th, using a portable stadiometer. For the analysis, body mass index (BMI) was classified according to the age- and sex-specific percentiles defined by the US Centres for Disease Control and Prevention (CDC; Kuczmarski *et al.*, 2000) into two categories: <85 th percentile; and ≥ 85 th percentile.

Participants

Of the 1716 participants evaluated both at the baseline (2003/2004) and at the follow-up (2007/2008), 225 adolescents (91 females and 134 males) were excluded with missing information for anthropometric measurements or BP, and 88 (45 female and 43 male) adolescents who did not report data to estimate sleep duration. Thus, this study was based on 1403 participants (757 females and 646 males).

Statistical analysis

Distribution of quantitative variables was checked using the Shapiro–Wilk test, and Mann–Whitney or Kruskal–Wallis tests were used to test comparisons. Chi-square test was used to compare qualitative variables.

In order to take in account the effect of height in BP and the change due to growth, the residues between SBP and DBP and height were calculated using linear regression models. Regression coefficients (β) and 95% confidence intervals (CIs) were computed to estimate the association between sleep duration and SBP and DBP using linear regression models, crude and adjusted for BMI (model 1) and for BMI plus practice of sports at 17 years old (model 2).

All of the analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 18.0, and the level of statistical significance was set at 0.05.

RESULTS

The adolescents not included in the present analysis were mostly male (56.7% versus 46.0%, $P = 0.001$). Included participants, males and females, had parents with a significant lower level of education, had higher sleep duration and females had higher DBP. For the remaining variables (SBP, drink, practice of sports and depressive symptomatology), no significant differences were found between those included and those not included.

Table 1 Participants' characteristics at 13 and 17 years of age

	Females, n (%)	Males, n (%)	P value
Age at menarche			
>12 years or not yet	245 (32.7)		
12 years	258 (34.4)		
>7 years and ≤ 11 years	247 (32.9)		
Parent's education, years			0.001
0–6	180 (24.9)	118 (18.6)	
7–9	145 (20.0)	124 (19.6)	
10–12	198 (27.3)	183 (28.9)	
≥ 13	201 (27.8)	209 (33.0)	
Family history of hypertension			0.552
No	470 (70.9)	382 (69.0)	
Yes	173 (26.1)	161 (29.1)	
Do not know	20 (3.0)	11 (2.0)	
13 years			
Blood pressure, mmHg*			
SBP	111 (11.0)	115 (12.0)	<0.05
DBP	68 (8.0)	67 (8.0)	0.623
Sleep duration, h day ⁻¹ *	8.99 (0.77)	9.06 (0.73)	0.120
Sleep duration			0.119
≤ 7 h	8 (1.1)	2 (0.3)	
>7 h	749 (98.9)	644 (99.7)	
Smoke			0.001
Ever	183 (24.6)	108 (17.4)	
Drink			0.091
Ever	426 (57.2)	331 (52.6)	
Practice of sports			<0.05
Yes	311 (41.8)	408 (63.8)	
Quartiles of caffeine intake, mg			0.039
≤ 11.74	170 (25.8)	143 (25.0)	
11.75–23.61	171 (25.9)	142 (24.8)	
23.62–45.95	153 (23.2)	150 (26.2)	
>45.95	165 (25.0)	137 (24.0)	
BDI	7.62 (7.32)	4.54 (5.61)	<0.05
BMI, kg m ⁻²			0.024
<85th percentile	592 (78.5)	473 (73.3)	
≥ 85 th percentile	162 (21.5)	172 (26.7)	
17 years			
Blood pressure, mmHg*			
SBP	111 (11.0)	115 (12.0)	<0.05
DBP	66 (8.0)	69 (10.0)	<0.05
Sleep duration, h day ⁻¹ *	8.29 (1.19)	8.20 (1.09)	0.151
Sleep duration			0.253
≤ 7 h	116 (15.3)	85 (13.2)	
>7 h	641 (84.7)	561 (86.8)	
Smoke			0.537
Ever	327 (43.3)	268 (41.6)	
Drink			0.282
Ever	625 (82.7)	547 (84.8)	
Practice of sports			<0.05
Yes	310 (41.8)	457 (72.5)	
Quartiles of caffeine intake, mg			0.837
≤ 11.74	164 (24.9)	143 (25.0)	
11.75–23.61	173 (26.3)	135 (23.6)	
23.62–45.95	153 (23.3)	155 (27.1)	
>45.95	168 (25.5)	139 (24.3)	
BDI	7.59 (7.28)	4.20 (4.90)	<0.05
BMI, kg m ⁻²			0.018
<85th percentile	631 (84.1)	511 (79.6)	
≥ 85 th percentile	119 (15.9)	131 (20.4)	

*Mean (SD); BDI, Beck depression inventory; BMI, body mass index.

Table 2 Cross-sectional and longitudinal associations between sleep duration and BP at 17 years old

Crude β (95% CI)*		Adjusted β (95% CI)*				
		Model 1		Model 2		
		SBP	DBP	SBP	DBP	
Sleep duration at 17 years old						
Females	0.747 (0.027; 1.467) [‡]	0.389 (−0.164; 0.943)	0.705 (−0.003; 1.412)	0.365 (−0.183; 0.912)	0.730 (0.005; 1.455) [‡]	0.388 (−0.173; 0.949)
Males	0.281 (−0.615; 1.177)	0.094 (−0.650; 0.837)	0.350 (−0.525; 1.225)	0.166 (−0.572; 0.904)	0.191 (−0.694; 1.075)	0.003 (−0.745; 0.750)
Sleep duration at 13 years old						
Females	0.382 (−0.728; 1.491)	0.286 (−0.566; 1.138)	0.212 (−0.879; 1.304)	0.184 (−0.659; 1.028)	0.232 (−0.900; 1.365)	0.102 (−0.773; 0.977)
Males	−2.113 (−3.428; −0.798) [‡]	−0.138 (−1.238; 0.962)	−1.873 (−3.156; −0.589) [‡]	−0.025 (−1.113; 1.064)	−1.938 (−3.229; −0.647) [‡]	−0.105 (−1.203; 0.993)

CI, confidence interval; DBP, diastolic blood pressure; SBP, systolic blood pressure.

*Cross-sectional and longitudinal associations using analysis of residues.

[†]Model 1: adjusted for BMI at 17 years old.

Model 2: adjusted for practice of sports and BMI at 17 years old.

[‡] $P < 0.05$.

The mean (standard deviation) sleep duration at 13 years old was 9.0 (0.76) h, and it decreased to 8.25 (1.14) h at 17 years old. No significant differences on sleep duration were found between genders at 17 years old [8.29 (1.19) h in girls versus 8.20 (1.09) h in boys; $P = 0.131$; Table 1].

The prevalence of hypertension (SBP and/or DBP equal to or above the 95th percentile) at 13 years old was 17.3%, and was 13.5% at 17 years old, being significantly higher in males at both ages (18.6% versus 16.2%, $P = 0.028$ at 13 years old; and 15.8% versus 11.6%, $P < 0.05$).

The prevalence of high BP (SBP and/or DBP equal to or above the 90th percentile) at 17 years old was 21.8%, higher among males (26.9%) than among females (18.1%), $P < 0.001$. In both genders, BP was positively associated with BMI at 13 years old and at 17 years old. Additionally, among females, it was found that the higher the age at menarche the lower the SBP. No other characteristics showed a significant effect on BP.

Regarding the cross-sectional relation at 17 years old, higher levels of BP were observed among those sleeping more hours per day, in both genders. Similar results were found after adjusting for sleep at 13 years old. In longitudinal analysis, females who had a higher sleep duration had higher levels of SBP and DBP. Among males, an inverse association was found, where those who had higher sleep duration had lower levels of SBP and DBP (Table 2).

After adjustment for BMI and practice of sports, the cross-sectional analysis at 17 years old showed a positive association between sleep duration and BP in females, but this was only significant regarding SBP [$\beta = 0.730$ (95% CI: 0.005; 1.455)]. Using the longitudinal approach, no significant association was found between sleep duration at 13 years old and BP at 17 years old in females. In males, a negative association was found: $\beta = -1.938$ (95% CI: −3.229; −0.647) regarding SBP and $\beta = -0.105$ (95% CI: −1.203; 0.993) for DBP (Table 2).

DISCUSSION

In this study, it was found that sleep duration decreased from 13 to 17 years old, in both genders, which is in accordance with data previously described in the literature (Iglowstein *et al.*, 2003). At 17 years old, sleep duration was higher in females than in males, as found in a review that summarized the sleep patterns in young people aged 9.0–18.8 years over the last 30 years (Olds *et al.*, 2010). However, and similar to the current results, other studies reported no differences in sleep duration between genders (Ghanizadeh *et al.*, 2008; Iglowstein *et al.*, 2003).

The current results showed a decrease in prevalence of hypertension from the age of 13 to 17 years, in both genders. This decrease may be related to a lower white-coat effect, as adolescents in follow-up were more familiar with measurements, but also by a significant decrease in BMI between 13 years old and 17 years old (Araujo *et al.*, 2014).

Regarding the effect of sleep duration at 17 years old on BP, it was found that longer sleep duration predicted higher levels of SBP in females. This result is not in accordance with studies in adolescents reporting an increase in SBP among those with short sleep (Javaheri *et al.*, 2008; Kuciene and Dulskiene, 2014; Mezick *et al.*, 2012). However, in the current study the mean sleep at 17 years old was 8 h per day, and few adolescents reported short sleep duration (less than 7 h day^{−1}) when compared with other studies (Carskadon *et al.*, 1998; Javaheri *et al.*, 2008; Tremaine *et al.*, 2010), which may explain the current result. Similarly to the results presented here, Sampei *et al.* (2006) found high SBP values among schoolchildren who slept more than 10 h, and found no association with DBP. Evidence for an association between longer sleep duration and an increased risk of high BP was also found by Guo *et al.* (2011) among girls aged 15–18 years, and in the authors' previous study regarding 13-year-old adolescents (Paciencia *et al.*, 2013). The

differences in this set of studies suggest a possible J-shaped curve, with higher BP values among those with short sleep but also among those with longer sleep duration.

In the longitudinal approach, no association was found between sleep duration and BP in females, but in males longer sleep duration was associated with lower values of BP. The result in males is in accordance with data on adults showing that those who sleep less hours were significantly more likely to be hypertensive over the follow-up period (Gangwisch *et al.*, 2006). However, to the authors' knowledge, this is the first study that evaluates the association between sleep duration and BP through a longitudinal approach among adolescents. This effect was only found in the longitudinal approach. This could represent a higher effect of exposures during early adolescence that may then define patterns of behaviour that persist during the following years, thus promoting a cumulative lifelong effect.

The explanation of an inverse association only in males, despite sleep duration being similar in both genders, may be related to differences in sleep needs by gender, with females needing comparatively less sleep than males (Olds *et al.*, 2010).

Additionally, during adolescence females are biologically more developed than males at the same chronological age (Rogol *et al.*, 2000). So, if in males sexual maturation occurs later, a delay in the decrease in sleep needs is also expected. Consequently, at the same chronological age, males probably need to sleep longer.

In both cross-sectional and longitudinal approaches, a stronger association was found regarding SBP levels than DBP. This result is in accordance with the higher variability of SBP values than DBP values (Basile, 2002), and with other studies that also found SBP to be more affected by sleep duration than DBP both in children (Sampei *et al.*, 2006) and among adults (Bjorvatn *et al.*, 2007). The longitudinal and cross-sectional approaches allow to clarify the effect of sleep duration on BP at different ages, and to identify that early adolescence may be more important than late adolescence.

The major limitation of this study is the use of a self-reported questionnaire to estimate sleep duration. The actigraphy monitoring device provides more sustained and less subjective assessments, and several studies have confirmed the validity and reliability of actigraphic estimates of sleep patterns in adolescents (Kushida *et al.*, 2001; Sadeh, 2011). However, a study of high-school adolescents found that self-reported total sleep duration is moderately correlated with actigraphy ($r = 0.53$), and that self-reported bedtimes and wake-up times are highly correlated with actigraphy ($r = 0.70$ and $r = 0.77$, respectively; Wolfson *et al.*, 2003). Thus, even with the limitations on the accurate quantification of sleep time, it can be accepted that the current measure is good enough to discriminate participants according to their sleep duration. Data on bedtimes and wake-up times on weekends were not recorded, which is also a limitation of this study. A compensatory response at the weekends may help to minimize the effects of short sleep duration on weekdays

(Moore and Meltzer, 2008). Another limitation of this study is related to the measurement of BP, because BP may vary throughout the day and from day to day (Javaheri *et al.*, 2008), and the use of one isolated measurement may have resulted in overestimation of the BP values (Barnett *et al.*, 2005; Sorof *et al.*, 2004). Nevertheless, the BP measurement was taken at school, in the adolescents' normal environment, which would have helped to reduce any 'white-coat' effect (Ramos and Barros, 2005). A high prevalence of hypertension was also found among adolescents in other Portuguese studies (Duarte *et al.*, 2000; Macedo *et al.*, 1997), and these results are consistent with the higher prevalence of hypertension in adult Portuguese populations (von Hafe *et al.*, 1997; Macedo *et al.*, 2005). Because BP in adolescence is associated with BP in adults (Chen and Wang, 2008), it is expected that the values in Portuguese adolescents are higher than those of other populations. Additionally, even assuming an overestimation on BP values the effect is expected to be independent of sleep duration.

Although this study presents some limitations, there are also important strengths. The major strength of this study is the longitudinal approach, as it allows the assessment of the effect of sleep duration at early adolescence on BP in older adolescents.

Another strength is related to the population approach, as in Portugal school education is compulsory at 13 years old (age at the assembling of the cohort) and the proportion of participation was high at baseline and also at follow-up, so therefore there was a good representation of the sample. The exclusion of some participants with missing information may limit the extrapolation of the results. However, in general, no significant differences were found and differences related to gender were minimized by stratification by gender so that differences do not affect the association between sleep duration and BP. On the other hand, those who were included in the study had shorter sleep duration, so it is expected that the prevalence of short sleepers is overestimated, but it is not clear if that affected the association between sleep duration and BP. The significant difference on DBP found between included and not-included females is not clinically relevant as the levels observed were very close.

CONCLUSION

The results from this study suggest that sleep duration could play a role in the aetiology of hypertension in adolescents. Additionally, these results support a stronger effect of sleep duration at 13 years old than at 17 years old, reinforcing the fact that sleep duration can be a determinant of BP levels from a young age. The gender effect may reflect differences in biological maturation, as girls tend to reach maturity earlier than males and females at this age need less sleep duration. However, it is important to recognize that sleep quality can be important to understand the association between sleep duration and BP.

The current results support the relevance of sleep duration for healthy lifestyles and as a possible target for preventive measures. Further studies are also needed to evaluate sleep needs in both genders and to understand their effect on BP levels.

ACKNOWLEDGEMENTS

This study was supported through FEDER from the Operational Programme Factors of Competitiveness – COMPETE and through national funding from the Portuguese Foundation for Science and Technology – FCT (Portuguese Ministry of Education and Science) within the project PTDC/DTP-EPI/6506/2014, and by the Epidemiology Research Unit – Institute of Public Health, University of Porto (UID/DTP/047507/2013). An individual grant attributed to JA (SFRH/BD/78153/2011) was supported by the Portuguese Foundation for Science and Technology – FCT.

CONFLICT OF INTEREST

All the authors read and approved the final manuscript, and declare no potential conflict of interests.

AUTHOR CONTRIBUTIONS

IP carried out the analyses and drafted the initial manuscript; JA helped in the analyses and reviewed the manuscript; and ER coordinated and supervised data collection, oversaw the developed study, critically reviewed the manuscript, and approved the final manuscript as submitted.

REFERENCES

American Academy of Pediatrics The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics*, 2004, 114: 555–576.

Araujo, J., Severo, M., Lopes, C. and Ramos, E. Food sources of nutrients among 13-year-old Portuguese adolescents. *Public Health Nutr.*, 2011, 14: 1–9.

Araujo, J., Barros, H., Severo, M., Lopes, C. and Ramos, E. Longitudinal changes in adiposity during adolescence: a population-based cohort. *BMJ Open*, 2014, 4: e004380.

Barnett, A. G., Van Der Pols, J. C. and Dobson, A. J. Regression to the mean: what it is and how to deal with it. *Int. J. Epidemiol.*, 2005, 34: 215–220.

Basile, J. N. Systolic blood pressure: it is time to focus on systolic hypertension-especially in older people. *BMJ*, 2002, 325: 26.

Beck, A., Steer, R. and Brown, G. *Manual for the Beck Depression Inventory-II*. Psychological Corp, San Antonio, TX, 1996.

Bjorvatn, B., Sagen, I. M., Oyane, N. *et al.* The association between sleep duration, body mass index and metabolic measures in the Hordaland Health Study. *J. Sleep Res.*, 2007, 16: 66–76.

Carskadon, M. A., Wolfson, A. R., Acebo, C., Tzischinsky, O. and Seifer, R. Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. *Sleep*, 1998, 21: 871–881.

Chen, X. and Wang, Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. *Circulation*, 2008, 117: 3171–3180.

Chobanian, A. V., Bakris, G. L., Black, H. R. *et al.* The seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. *JAMA*, 2003, 289: 2560–2572.

Coelho, R., Martins, A. and Barros, H. Clinical profiles relating gender and depressive symptoms among adolescents ascertained by the Beck Depression Inventory II. *Eur. Psychiatry*, 2002, 17: 222–226.

Din-Dzietham, R., Liu, Y., Bielo, M. V. and Shamsa, F. High blood pressure trends in children and adolescents in national surveys, 1963 to 2002. *Circulation*, 2007, 116: 1488–1496.

Duarte, J., Guerra, S., Ribeiro, J. and Mota, J. Tensão arterial em idades pediátricas (8-13 anos) na área do grande Porto. *Rev. Port. Cardiol.*, 2000, 19: 809–820.

Durmer, J. S. and Dinges, D. F. Neurocognitive consequences of sleep deprivation. *Semin. Neurol.*, 2005, 25: 117–129.

Gangwisch, J. E., Heymsfield, S. B., Boden-Albala, B. *et al.* Short sleep duration as a risk factor for hypertension: analyses of the first National Health and Nutrition examination survey. *Hypertension*, 2006, 47: 833–839.

Ghanizadeh, A., Kianpoor, M., Rezaei, M. *et al.* Sleep patterns and habits in high school students in Iran. *Ann. Gen. Psychiatry*, 2008, 7: 5.

Guo, X., Zheng, L., Li, Y. *et al.* Association between sleep duration and hypertension among chinese children and adolescents. *Clin. Cardiol.*, 2011, 34: 774–781.

von Hafe, P., Andrade, M. J., Fernando, P. B. *et al.* Prevalência, conhecimento, tratamento e controlo da hipertensão arterial no Porto. *Portugal. Rev. Port. Cardiol.*, 1997, 16: 683–690.

Iglowstein, I., Jenni, O. G., Molinari, L. and Largo, R. H. Sleep duration from infancy to adolescence: reference values and generational trends. *Pediatrics*, 2003, 111: 302–307.

Javaheri, S., Storfer-Isser, A., Rosen, C. L. and Redline, S. Sleep quality and elevated blood pressure in adolescents. *Circulation*, 2008, 118: 1034–1040.

Kato, M., Phillips, B. G., Sigurdsson, G. *et al.* Effects of sleep deprivation on neural circulatory control. *Hypertension*, 2000, 35: 1173–1175.

Knutson, K. L., Spiegel, K., Penev, P. and Van Cauter, E. The metabolic consequences of sleep deprivation. *Sleep Med. Rev.*, 2007, 11: 163–178.

Kuciene, R. and Dulskiene, V. Associations of short sleep duration with prehypertension and hypertension among Lithuanian children and adolescents: a cross-sectional study. *BMC Public Health*, 2014, 14: 255.

Kuczmarski, R. J., Ogden, C. L., Grummer-Strawn, L. M. *et al.* CDC growth charts: United States. *Adv. Data*, 2000, 314: 1–27.

Kushida, C. A., Chang, A., Gadkary, C. *et al.* Comparison of actigraphic, polysomnographic, and subjective assessment of sleep parameters in sleep-disordered patients. *Sleep Med.*, 2001, 2: 389–396.

Laberge, L., Petit, D., Simard, C. *et al.* Development of sleep patterns in early adolescence. *J. Sleep Res.*, 2001, 10: 59–67.

Lopes, C., Aro, A., Azevedo, A., Ramos, E. and Barros, H. Intake and adipose tissue composition of fatty acids and risk of myocardial infarction in a male Portuguese community sample. *J. Am. Diet. Assoc.*, 2007, 107: 276–286.

Lurbe, E. Childhood blood pressure: a window to adult hypertension. *J. Hypertens.*, 2003, 21: 2001–2003.

Macedo, E., Lopes, L., Pereira, A. and Falcão-Freitas, A. Normogramas de pressão arterial em crianças e adolescentes de acordo com a idade e a altura. *Rev. Port. Cardiol.*, 1997, 16: 679–682.

- Macedo, M. E., Lima, M. J., Silva, A. O. *et al.* Prevalence, awareness, treatment and control of hypertension in Portugal: the PAP study. *J. Hypertension*, 2005, 23: 1661–1666.
- Meerlo, P., Sgoifo, A. and Suchecki, D. Restricted and disrupted sleep: effects on autonomic function, neuroendocrine stress systems and stress responsivity. *Sleep Med. Rev.*, 2008, 12: 197–210.
- Mezick, E. J., Hall, M. and Matthews, K. A. Sleep duration and ambulatory blood pressure in black and white adolescents. *Hypertension*, 2012, 59: 747–752.
- Moore, M. and Meltzer, L. J. The sleepy adolescent: causes and consequences of sleepiness in teens. *Paediatr. Respir. Rev.*, 2008, 9: 114–120; quiz 20–21.
- Muntner, P., He, J., Cutler, J. A., Wildman, R. P. and Whelton, P. K. Trends in blood pressure among children and adolescents. *JAMA*, 2004, 291: 2107–2113.
- Nixon, G. M., Thompson, J. M., Han, D. Y. *et al.* Short sleep duration in middle childhood: risk factors and consequences. *Sleep*, 2008, 31: 71–78.
- Olds, T., Blunden, S., Petkov, J. and Forchino, F. The relationships between sex, age, geography and time in bed in adolescents: a meta-analysis of data from 23 countries. *Sleep Med. Rev.*, 2010, 14: 371–378.
- Paciência, I., Barros, H., Araujo, J. and Ramos, E. Association between sleep duration and blood pressure in adolescents. *Hypertens. Res.*, 2013, 36: 747–752.
- Ramos, E. and Barros, H. Prevalence of hypertension in 13-year-old adolescents in Porto. *Portugal. Rev. Port. Cardiol.*, 2005, 24: 1075–1087.
- Ramos, E. and Barros, H. Family and school determinants of overweight in 13-year-old Portuguese adolescents. *Acta Paediatr.*, 2007, 96: 281–286.
- Rey-Lopez, J. P., De Carvalho, H. B., De Moraes, A. C. *et al.* Sleep time and cardiovascular risk factors in adolescents: the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. *Sleep Med.*, 2014, 15: 104–110.
- Rogol, A. D., Clark, P. A. and Roemmich, J. N. Growth and pubertal development in children and adolescents: effects of diet and physical activity. *Am. J. Clin. Nutr.*, 2000, 72: 521S–528S.
- Sadeh, A. The role and validity of actigraphy in sleep medicine: an update. *Sleep Med. Rev.*, 2011, 15: 259–267.
- Sampei, M., Dakeishi, M., Wood, D. C. and Murata, K. Impact of total sleep duration on blood pressure in preschool children. *Biomed. Res.*, 2006, 27: 111–115.
- Shaikh, W. A., Patel, M. and Singh, S. Association of sleep duration with arterial blood pressure profile of gujarati Indian adolescents. *Indian J. Community Med.*, 2010, 35: 125–129.
- Sorof, J. M., Lai, D., Turner, J., Poffenbarger, T. and Portman, R. J. Overweight, ethnicity, and the prevalence of hypertension in school-aged children. *Pediatrics*, 2004, 113: 475–482.
- Sun, S. S., Grave, G. D., Siervogel, R. M. *et al.* Systolic blood pressure in childhood predicts hypertension and metabolic syndrome later in life. *Pediatrics*, 2007, 119: 237–246.
- Tremaine, R. B., Dorrian, J. and Blunden, S. Subjective and objective sleep in children and adolescents: measurement, age, and gender differences. *Sleep Biol. Rhythms*, 2010, 8: 229–238.
- Wang, Y., Mei, H., Jiang, Y. R. *et al.* Relationship between duration of sleep and hypertension in adults: a meta-analysis. *J. Clin. Sleep Med.*, 2015, 11: 1047–1056.
- Wolfson, A. R., Carskadon, M. A., Acebo, C. *et al.* Evidence for the validity of a sleep habits survey for adolescents. *Sleep*, 2003, 26: 213–216.